Lake Cathie / Lake Innes Sustainability Assessment Report

July 2007

Jenifer Ticehurst, Rebecca Letcher and Robert Mezzatesta

CLIENT REPORT 2007/ 20

Integrated Catchment Assessment and Management (iCAM) Centre
The Australian National University

PROJECT: Coastal Lake Assessment and Management (CLAM) – Phase 2

CLIENT: Northern Rivers Catchment Management Authority

☐ RESTRICTED DISTRIBUTION ☒ PUBLIC DISTRIBUTION

Ticehurst, J., Letcher, R., Mezzatesta, R. (2007). Lake Cathie / Lake Innes Sustainability Assessment Report, July 2007, iCAM Client Report 2007/20, The Australian National University, Canberra, ACT.

DIRECTOR: Professor Tony Jakeman

Building 48a, Linneaus Way
The Australian National University ACT 0200
Phone (02) 6125 4742 Fax (02) 6125 0757
Email: tony.jakeman@anu.edu.au

ALL QUERIES CAN BE ADDRESSED TO:
Dr Rebecca Letcher
Building 48a, Linneaus Way
The Australian National University ACT 0200
Phone: 0438 230 246
Email: rebecca.letcher@anu.edu.au

CONTACTS FOR THE LAKE CATHIE / LAKE INNES CLAM

The primary contact at the Port Macquarie/Hastings Shire Council for the Lake Cathie / Lake Innes CLAM is:

Matt Rogers
Natural Resources Manager
Port Macquarie Hastings Council
PO Box 84
Port Macquarie NSW 2444
(02) 6581 8635 (phone)
(02) 6581 8123 (fax)
Matt.Rogers@pmhc.nsw.gov.au

The consultant who developed the Lake Cathie / Lake Innes CLAM is:

Robert Mezzatesta
Manager, South East Queensland
Eco Logical Australia
PO Box 1191
Coolangatta QLD 4225
Ph: (07) 5536 1999
Fax: (07) 5536 1944
Mobile: 0400 373 037
robertm@ecoaus.com.au

CONTENTS

EXECUTIVE SUMMARY

This Sustainability Assessment report is based on results from the Coastal Lake Assessment and Management (CLAM) tool for Lake Cathie / Lake Innes. This tool was developed as part of the Northern Rivers Catchment Management Authority (CMA) funded project entitled 'Ensuring sustainable development in coastal lake catchments of NSW Northern Rivers (CLAM project)'.

The report summarises the quality of data in the Lake Cathie / Lake Innes CLAM for each node and also provides an assessment of key data gaps identified by Robert Mezzatesta (Eco Logical Australia) in putting the Lake Cathie / Lake Innes CLAM together. These gaps are:

- nutrient concentration information in Lake Cathie, Cathie Ck and Lake Innes (P, N & TSS)
- policy information on runoff controls across the whole catchment (not just in Area 13/14)
- localised septics data (failure rate, leaching etc)
- updated flood modelling (current information is quite old)
- updated lake depths / bathymetry

A range of scenarios in the Lake Cathie / Lake Innes CLAM are analysed in this report, as recommended in a workshop with the Port Macquarie - Hastings Shire Council on 23rd May 2007:

- The development of Area 13 Thrumster and Area 14 Lake Cathie separately and in combination; and
- A suite of independent and combination impacts between the reversion of Lake Innes to freshwater, lower estuary shoaling and dredging, entrance management and sea level rise.

These are a small number of the total scenario options available in the CLAM but provide a useful insight into the Lake Cathie / Lake Innes CLAM and the management of the lake. Key conclusions from this analysis are summarised below.

Development of Area 13 Thrumster and Area 14 Lake Cathie

The options of full urban development in Areas 13 and 14 were compared to the no change option. The results show:

- Urban development within the Cathie catchment (Area 14) leads to a moderate decrease in the Lake Cathie water quality mainly through increases in Total Nitrogen (TN) and Total Phosphorous (TP).
- Urban development within the Innes catchment (Area 13) leads to a very small decrease in the Lake Innes water quality despite a small to moderate increase in TN, TP and TSS (Total Suspended Sediments). The small impact in the lake water quality from the catchment inputs is most likely due to the larger size of the lake compared to its catchment.
- The estuary water quality is likely to decrease a very small to small amount following development, with a corresponding decrease in seagrass.
- If either of the proposed urban developments were to occur then fire risk is likely to increase but the risk is more significant for the Area 13 development then for Area 14. This change in fire risk would be the cause for the very small decrease predicted for flora and fauna following the area 13 development.
- Domestic pets are likely to moderately increase if the Area 13 development was to be approved. This increase along with the increases in fire risk, are likely to lead to a very small to small increase in the council costs.

Combination impacts between Reversion of Lake Innes to freshwater, Lower estuary shoaling and dredging, Entrance management and Sea level rise

A suite of combination impacts between the reversion of Lake Innes to freshwater, lower estuary shoaling and dredging, entrance management and sea level rise are compared to the no change option. The results show:

- Natural entrance management through a large increase in tidal flushing creates a large increase in the estuary water quality, which is the most likely reason for the moderate decrease in algal blooms.
- Dredging the lower estuary leads to a small increase in council management, but reverting to a natural entrance management regime creates a small decrease in council management. Together a very small increase in council management is predicted.
- Natural reversion to freshwater in Lake Innes and a change to natural entrance management generates many positive impact for the systems ecology, leading to increases in flora and fauna, lake productivity and migratory birds, but commercial fishing and prawning is more likely to decrease under these scenarios.
- Sea level rise leads to a moderate increase in flood risk at mainly heights 1.8 to 2.5m (AHD), and if the entrance management was changed to a natural regime the impact would be larger.
- Recreation is quite insensitive to these scenarios but does reflect a very small increase from dredging and a very small decrease from natural entrance management, which is probably due to the expected small changes in boat navigation access. These changes are also reflected in tourism.
- Natural reversion to freshwater in Lake Innes creates a large increase in costs to State government due to planning which would only be marginally offset by a very small increase in local revenue. Together with a change to natural entrance management the local revenue is likely to undergo a small increase, but this still appears very unlikely to offset the costs of the required investigation to revert to a freshwater system.
- Under the current sea level, natural entrance management is most likely to lead to an increase in seagrass, but if sea level increases under the natural entrance management regime then it is likely that the lake water level will increase to a point that it is less favourable for seagrass so the change to seagrass will be less.
- An increase in sea level is predicted to create a very small increase in wetland vegetation. However, the impact upon wetland vegetation, which is predicted to increase, is clearly dominated by the natural reversion to freshwater of Lake Innes and natural entrance management, regardless of the sea level.

1 INTRODUCTION

This Sustainability Assessment report is based on results from the Coastal Lake Assessment and Management (CLAM) tool for Lake Cathie / Lake Innes. This tool was developed as part of the Northern Rivers Catchment Management Authority (CMA) funded project entitled 'Ensuring sustainable development in coastal lake catchments of NSW Northern Rivers (CLAM project)'. The CLAM approach was developed in a joint effort by the Australian National University and the Department of Environment and Climate Change. Its objective was to fill the need for Sustainability Assessments of coastal lake systems identified in the Healthy Rivers Commission Independent Inquiry into Coastal Lakes. It is considered to be a key tool to assist in management and planning processes such as the Local Environmental Planning review and development of Estuary Management Plans.

Scenarios presented in this report were identified as an important primary focus during workshops held with Council staff and other stakeholders in May 2007. These scenarios represent a relatively small subset of the complete range of options available in the CLAM tool and are intended to:

- document the quality of data used in the Lake Cathie / Lake Innes CLAM and key data gaps which are a priority for data collection
- provide a useful analysis of options of first concern to Council and other key stakeholders which can be incorporated in decision making and other planning activities on these issues; and,
- illustrate the way in which the CLAM tool can be used to show the trade-offs involved in managing the lake system.

This report is not a management plan and cannot take the place of activities associated with the development of such a plan. In particular this report did not include scope for comprehensive community consultation. It can however be used to inform such a planning process. When this occurs, results in this report must be critically evaluated and open to criticism from members of the public. This needs to occur within the context of the supporting documentation provided in the input pages of the CLAM tool. These pages provide comprehensive documentation of the assumptions underlying data used to derive the results in this report. This information is provided to allow users to assess for themselves the varying quality of data sources underlying the CLAM tool and its relevance to the decisions being made.

1.1 What is CLAM?

The Coastal Lake Assessment and Management (CLAM) tool was developed to allow stakeholders to assess the social, economic, environmental and ecological trade-offs associated with development, remediation, and use options for coastal lakes and estuaries. A population shift towards the coastal fringe in NSW has seen substantial pressures being placed on these coastal systems. Catchment areas are subject to a variety of activities including urban developments, forestry and agricultural activities, recreation and tourism, and commercial fishing and aquaculture activities. Remediation of impacts through better controls on developments and estuary activities, as well as replanting of riparian areas and fringing wetlands, are frequently being considered by State and Local authorities.

The CLAM tool shows the multitude of impacts arising from such pressures and potential remediation measures. It is most appropriate for strategic planning purposes such as the development of estuary management plans or coastal zone management plans. It delivers a high level of community participation and an open and transparent modelling tool, which provides full detail of assumptions made and data used in its population.

The CLAM approach is based on the concept of Bayesian networks but provides additional decision support through tailored interfaces and in-model documentation of model assumptions and design process. More details on the development and use of CLAM models can be found in Merritt *et al.* (2006a, 2006b) and Ticehurst *et al.* (2005, 2007).

There are six main benefits which the CLAM is able to capture for strategic decision making and management activities:

- It allows integration of existing data sets and reports;
- It documents in a transparent way data and assumptions available to be used in making a decision;
- It allow such data and assumptions to be applied repeatedly over many (often 100,000's) iterations in a consistent manner to improve the consistency and rigour of decision making;
- It provide a sound prioritisation of key data and information gaps in the management of a lake system through open documentation of data used in the CLAM system and analysis of the implications of the uncertainty of this data for decision making;
- It plays an education role, providing a tool for people to focus on learning more about the interactions between human actions and social, environmental and economic outcomes in the system;
- It provides a focus for negotiations and discussions about preferred management actions. The CLAM approach encourages people to verbalise and document why they agree or disagree with model results. This type of discourse can form a key component of any negotiation about preferred options and the nature of impacts on the system. Improved understanding and knowledge developed through such discussions and studies which come out of them can be used to update the knowledge in the CLAM system.

1.2 Context for the CLAM and this Sustainability Assessment

The Coastal Lake Assessment and Management (CLAM) approach was developed as part of a NSW Government project focused on the coastal zone, the Comprehensive Coastal Assessment. In response to the Healthy Rivers Commission's Independent Inquiry into Coastal Lakes (2002), a Statement of Intent (SOI) was released by the Cabinet Office in February 2003 stating the Government's commitment to the implementation of the *Coastal Lakes Strategy* (reported in Rissik *et. al.,* 2003). The Healthy Rivers' Report recommended the development of Sustainability Assessment and Management Plans for coastal lake systems. The CLAM approach was developed as a Sustainability Assessment tool to assist in the development of such plans. This report also classified all coastal lakes in NSW according to the level of protection and management they required. Classifications were as follows:

- Comprehensive protection – all natural ecosystem processes restored and preserved;
- Significant protection – critical natural ecosystem processes restored and preserved;
- Healthy modified condition – key natural and/or highly valued modified ecosystem processes rehabilitated and retained;
- Targeted repair – habitat conditions for selected key species established.

The first stage of the SOI was to fund the development of sustainability assessments and management strategies of eight priority coastal lakes in NSW. These were Cudgen, Myall, Wollumboola, Burrill, Narrawallee, Coila, Merimbula and Back Lakes. The main aim of the project was to ensure that there is "*no further deterioration or that there is an improvement, in the condition of coastal lakes whilst detailed assessments are conducted (if required) and Lake Management Plans developed and implemented.*" (Rissik *et al.,* 2003).

The CLAM method was developed to enable interim management frameworks to be developed rapidly using the best available knowledge to inform short-term decisions while also providing the opportunity for more information to be collected and used to inform future longer-term decisions and plans. The approach also had to be transferable to other coastal lake systems.

Figure 1. Location of the Northern Rivers lake systems for which a CLAM tool was developed

The Lake Cathie / Lake Innes CLAM has been developed as part of a project funded by the Northern Rivers Catchment Management Authority (NRCMA) entitled "Ensuring sustainable development in coastal lake catchments of NSW Northern Rivers". This project was part of the Northern Rivers Catchment Management Authority (NRCMA) Coastal Management program. It addressed the draft Catchment Action Plan (CAP) Management Target C2: "By 2016 maintain and improve the condition of estuaries and coastal lakes through: completion of management plans for all estuaries (65% by 2009), and sustainability assessment and management plans for all coastal lakes (65% by 2009); and implementation of all priority NRM activities within those plans (65% by 2009)".
The project was funded by the Australian Government's Natural Heritage Trust Strategic Reserve 2004-05. As part of this project CLAMs have been developed for the Northern Rivers CMA area as shown in Figure 1.

This Sustainability Assessment report provides a summary of impacts relating to six key scenarios and their impacts, as recommended at the Lake Cathie / Lake Innes CLAM workshop with the Port Macquarie - Hastings Shire Council on23rd May 2007. These impacts affect the social, economic and environmental sustainability of the lake system.

This report is primarily intended for key decision makers in the Lake Cathie / Lake Innes system, including Council and CMA staff, members of the Estuary Management Committees and those in relevant State Government Agencies. It is also expected to be useful to those people involved in the development of environmental impact statements associated with future developments such as urban release areas. The report is likely to be of interest to a wider audience, particularly those likely to be affected by changes to the management of the lake system. As a companion to the Lake Cathie / Lake Innes CLAM, this report is useful in demonstrating the ways in which the CLAM can be used and results from it interpreted for management purposes. As such it is recommended to any user of the Lake Cathie / Lake Innes CLAM.

It should be noted that the scenarios presented in this report are not exhaustive. Additional scenarios are presented in the Lake Cathie / Lake Innes CLAM and should also be considered when a Sustainability Assessment and Management Plan is developed.

1.3 How should the CLAM tool and results in this Sustainability Assessment Report be used?

The Lake Cathie / Lake Innes CLAM tool and the results provided in this Sustainability Assessment report should be used sensibly. As with all models, results from the CLAM must be critically evaluated for their appropriateness before being used to make decisions. All assumptions used in populating the CLAM and any expert review of the data are documented in the input pages found with the CLAM model (see enclosed CD). This information must be very carefully considered when using results to make decisions or recommendations. Users should ask:

- Does the CLAM consider the specific scenarios you are interested in?
- Do the impacts look reasonable? If not, why not? If yes, why?
- Do you trust the data used to populate the model? Why/why not?
- Is there other better data available that could be used in the model or used to review/validate the results?

The CLAM has a strong potential to be used in negotiations between catchment stakeholders on management actions. It is also useful in an educational and capacity building role.

2 LAKE CATHIE / LAKE INNES

The information contained in the review given below has been taken from the '*Catchment Status*' page of the Lake Cathie / Lake Innes CLAM developed by Robert Mezzatesta (Eco Logical Australia).

2.1 Overview

The Lake Cathie / Lake Innes catchment is located on the mid north coast of NSW, south of Port Macquarie & about 400km north of Sydney (152° 45' 00', 31° 30' 14'). The catchment covers about 92 km^2, with approximately 6.7 km^2 of waterway. The system is untrained and intermittently/mechanically opened and comprises of a shallow lake system with low-lying foreshore topography. Tidal discharges are weak and highly variable depending on the degree of entrance shoaling. The smaller lake, Lake Cathie, is almost entirely "marshland" and is joined to Lake Innes by Cathie Creek. Lake Cathie is a popular recreational swimming and fishing area, with a small commercial prawning industry supporting 20 families based within Lake Innes (NSW DNR 2006).

The catchment includes the small town of Lake Cathie which is sewered, located immediately south of the highly throttled entrance which connects the lake system to the sea. The two main areas of future urban development within the catchment lie immediately to the south of Lake Cathie, making up part of the future urban investigation area known as "Area 14"; and an area in the north west corner of the catchment, known as "Area 13", located west of Port Macquarie.

2.2 The Lake Systems

Historically, Lake Innes was the largest freshwater lake on the east coast of NSW until an attempt to drain it in 1933 created a permanent connection to the estuary and Lake Cathie via Cathie Creek, introducing a saline environment and regular flushing as the entrance opened.

The estuarine system is made up of Lake Cathie, Cathie Creek and Lake Innes, with the following broad characteristics:

	Lake Innes	Lake Cathie	Cathie Creek
Catchment Area	60,000ha	6,000ha	34,000ha
Mean Open Water Area	600ha	100ha	120ha
Major Drainage Inputs	Karikeree Creek, Honeysuckle Creek	Freshwater paperbark swamp	Cowarra Creek
Major Surrounding Land Use	Rural, Rural Residential, Urban and Nature Reserve		

2.3 Vegetation

Currently, Lake Innes includes the second largest estuarine saltmarsh area (6.0 km^2) in NSW, with its surrounding wetlands recorded as a renowned aquatic bird habitat (DNR 2006) which is utilised by a number of JAMBA and CAMBA listed migratory species and threatened species (DEWR 2007). The entire estuary is a designated wetland under SEPP14.

Conservation reserves in the area include:

- Lake Innes Nature Reserve (3,510ha), which contains Lake Innes, Cathie Creek, Lake Cathie and a large amount of surrounding vegetation; and
- Lake Innes State Conservation Area (1,159ha) adjoining the Lake Innes Nature Reserve in the south west of the catchment.

These two reserves consist of wet and dry heath, saltmarshes, open forests of Melaleuca/Casuarina, Blackbutt/Tallowwood and Flooded Gum/Brushbox. Pockets of rainforest provide seasonal food supply for both migratory and resident fruit-eating birds.

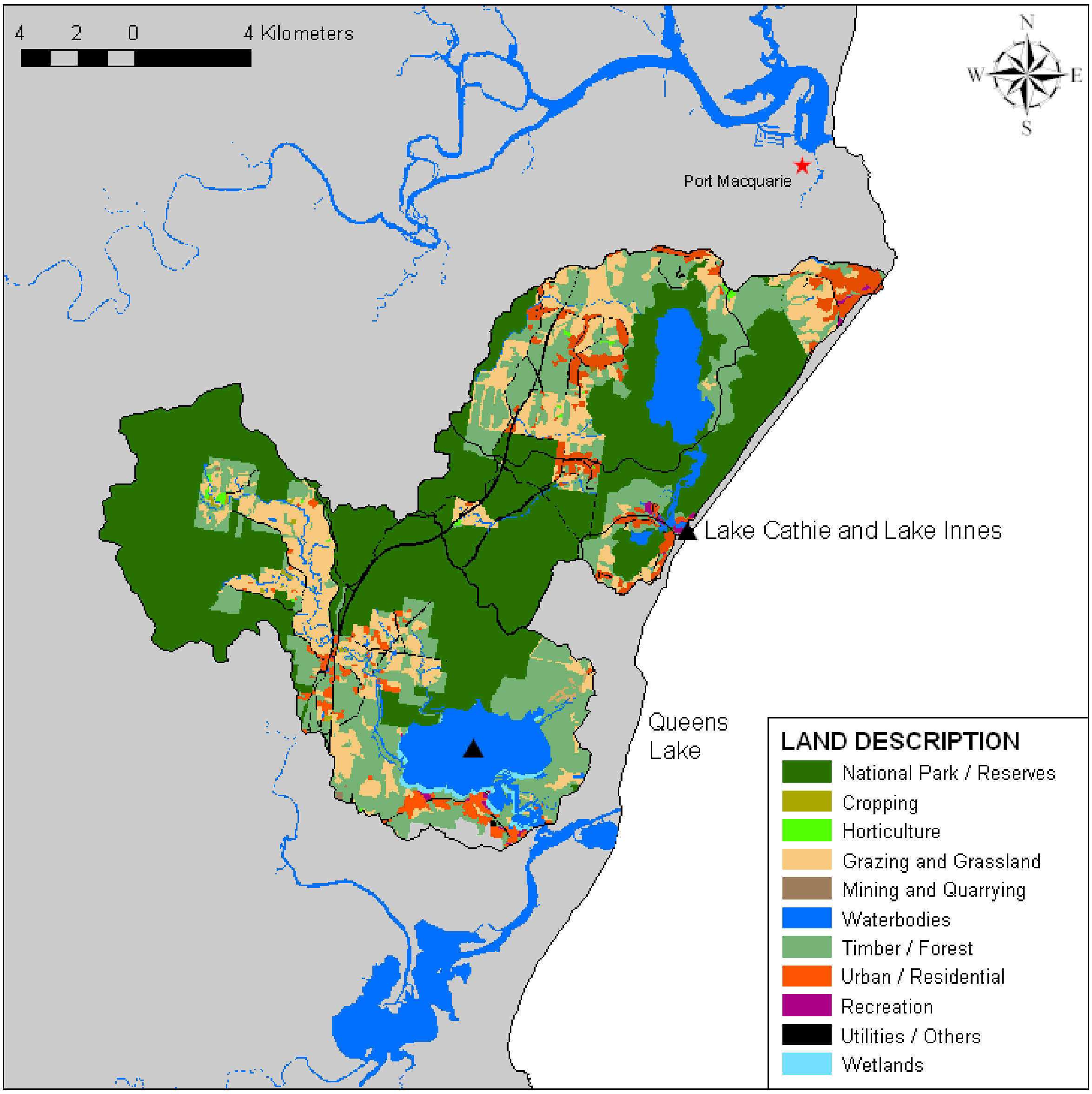

Figure 2. Lake Cathie / Lake Innes, its catchment and reference areas for scenarios

2.4 Water Quality Status

In general terms the water quality of the Lake Cathie / Lake Innes estuary is currently good and there are currently few indications of adverse water quality directly from human inputs. This is mainly due to the low disturbance in much of the catchment, the current low level of urban development and the filtering effect of the natural wetlands surrounding much of the open water bodies. Water quality does deteriorate from time to time following natural hydraulic and climatic processes in the intermittently opening estuary.

The opening of Lake Innes to the estuary has had a number of long term impacts on the hydraulics and water quality of the estuary. The connection of the lake to the estuary has led to a decrease in estuary opening rate and decreased tidal variation in the estuary when it is open to the sea. Water quality consequences of this include:

- conversion of Lake Innes from a fresh/brackish water lake to a brackish/hypersaline lake
- increased salinity fluctuations in the estuary as a whole with hypersalinity occurring faster in Lake Cathie and Cathie Creek
- more frequent instances of low & very low bottom dissolved oxygen levels through increased salinity & temperature stratification
- increase in overall turbidity and water colour levels in the estuary

The shallow nature of the shoals and channels in the entrance channel and Cathie Creek limit recreational activities, such as fishing, swimming and boating. These activities are also affected by aesthetic water quality attributes such as water clarity and colour plus high salinity as well as water level variation (Webb, McEown & Associates 1994).

2.5 Catchment Land Use

Table 1 shows the distribution of land use categories within the catchment. Nearly 70% of the catchment is made up of bushland, comprising mainly of Nature Reserve, State Recreation Area and State Forest. The waterbodies of Lake Innes, Lake Cathie and Cathie Creek comprise of over 7% of the catchment. Approximately 24% of the catchment has been cleared or modified.

Table 1. Land uses in Lake Cathie Lake Innes Catchment (from DNR land use mapping – GIS data)

Land Use	Area (ha)	%
Bushland/riparian/wetland	8209.5	69.5
Sand or Beach	3.2	0.0
Unimproved pasture	1613.4	13.7
Commercial/industrial	26.5	0.2
Urban/Residential	766.3	6.5
Roads	307.0	2.6
Water	888.7	7.5
Total	**11814.6**	**100.0**

3 LAKE CATHIE / LAKE INNES CLAM

3.1 Conceptual framework

The Lake Cathie / Lake Innes CLAM model is underpinned by the conceptual framework shown in Figure 3. This diagram shows the probable dependencies between scenarios (actions) and state variables (values or impacts). This demonstrates, for example, the way in which ecological outcomes such as seagrass are dependent on water level changes. These in turn depend on actions such as entrance management and uncontrolled influences such as sea level rise. Definitions for all nodes in this conceptual framework are provided in Appendix 1.

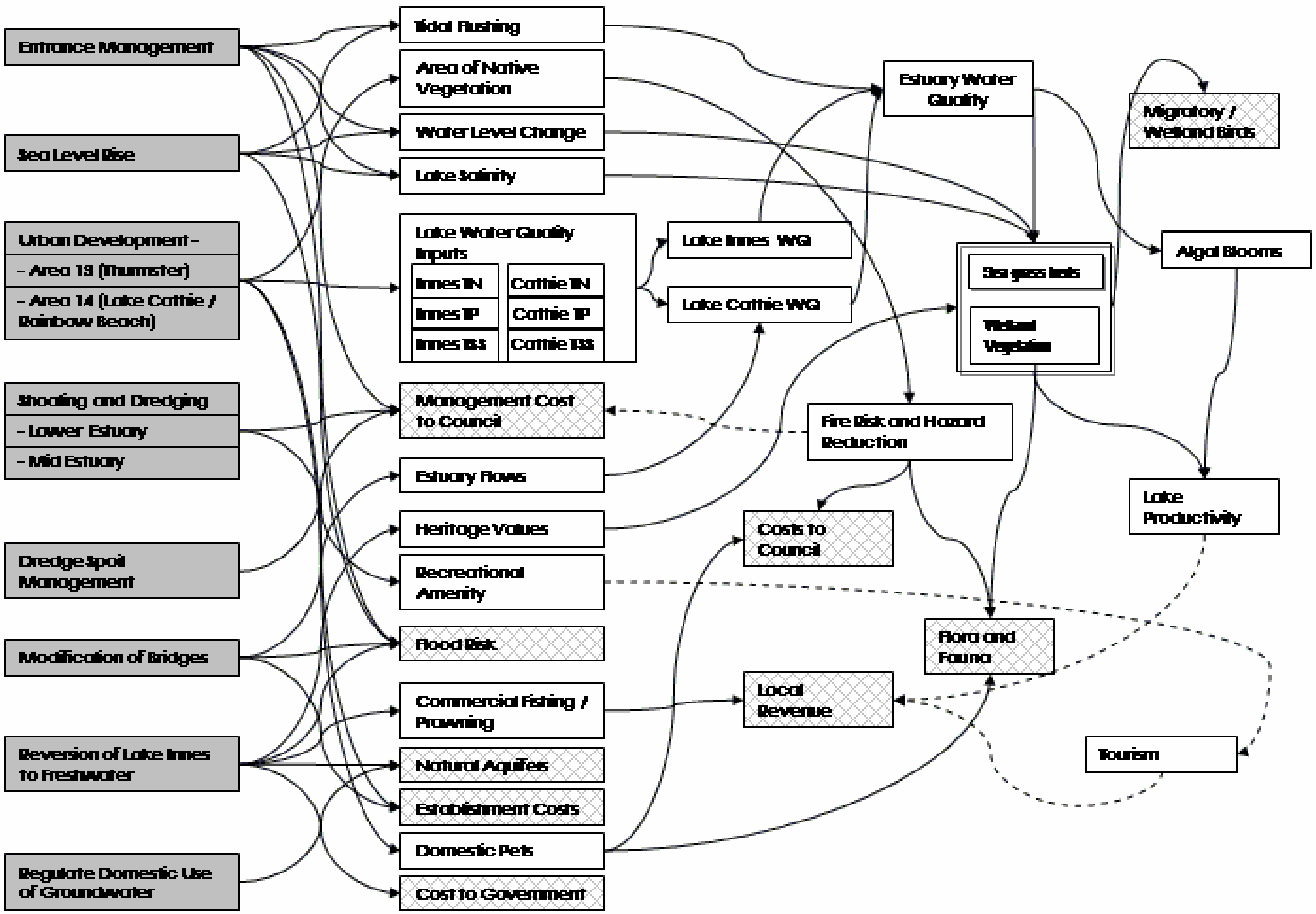

Figure 3. Lake Cathie / Lake Innes conceptual framework used to underpin the Lake Cathie / Lake Innes CLAM. Arrows show dependency between nodes. Dark grey boxes represent scenarios which are actions, such as modification of bridges, or potential future drivers of the system, such as sea level rise.

3.2 Consultation undertaken to develop the Lake Cathie / Lake Innes CLAM

The framework and scenarios contained in the Lake Cathie / Lake Innes CLAM were developed in consultation with various stakeholder groups. Major consultation was undertaken through the Port Macquarie - Hastings Shire Council. In particular Matt Rogers was involved in discussions of feasible scenarios, issues and concerns which were used to develop the conceptual framework. Feedback was also received on the issues, framework and scenarios from Eric Claussen & Louise Feltus (Department of Environment and Climate Change – Parks and Wildlife division), Robert Kasmarik and Glenn Atkinson (Department of Environment and Climate Change), Jack Jones & John Hunt (Lake Cathie Progress Association), Rob Tate (Landcare), Sandy McClimont (Residents Action Group), Trevor Corliss (Port Macquarie Conservation Society) and Peter Besseling (Office of Rob Oakshot – Member for Port Macquarie).

A second major source of feedback was the Project Reference Group which consists of representatives of the Northern Rivers Catchment Management Authority (CMA), the Department of Environment and Climate Change, the Department of Planning, the Department of Primary Industries and NSW Marine Parks Authority.

The CLAM user training workshops held in May 2007 provided an opportunity for feedback on the Lake Cathie / Lake Innes CLAM. Attendees at this workshop included Council staff, CMA representatives, staff from State Government Agencies and community members.

3.3 An assessment of data quality

The CLAM model relies on a set of conditional probabilities to define the relationship between variables. An example of a conditional probability is as follows: there is a 30% chance of rain tomorrow if it has rained today. That is, a conditional probability is the probability of event B (rain tomorrow) given that event A (rain today) has occurred.

Thus for every arrow in Figure 3, a set of conditional probabilities must be defined which estimates the nature of the relationship between the two variables. The data used to derive these conditional probabilities comes from a variety of sources. These include literature assumptions, calibrated and uncalibrated models, expert and local knowledge and observed data. For such a broad system a variety of data qualities is to be expected. This section provides an assessment of data quality for each node (ie. each box in Figure 3). A statement of priority data collection needs for Lake Cathie / Lake Innes is then given. This statement was provided by Robert Mezzatesta (Eco Logical Australia) who put together the data for the Lake Cathie / Lake Innes CLAM.

Table 2 provides a qualitative assessment of data quality for each node in the Lake Cathie / Lake Innes CLAM.

Table 2. Subjective assessment of the quality of data used in the Lake Cathie / Lake Innes CLAM

Node	Quality of Data	Reason	Suggested improvements
Algal blooms	Poor	Based upon assumptions from the literature without any local data or expert review	Expert review of assumptions

Proximity to vegetation	Average	Based upon assumptions with some local GIS data	Expert review of assumptions
Cathie TN	Average	Based upon uncalibrated iCAM water quality model using some local data	Expert review of input and output data
Cathie TP	Average	Based upon uncalibrated iCAM water quality model using some local data	Expert review of input and output data
Cathie TSS	Average	Based upon uncalibrated iCAM water quality model using some local data	Expert review of input and output data
Cathie Water Quality	Poor	Based upon assumptions and iCAM combination model	Expert review of assumptions and hydrodynamic model of the lake
Cost to Council	Poor	Based upon assumptions	Expert review of assumptions
Council Development Cost	Average	Based upon local report	Expert review for more current information
Council Management Cost	Poor	Based upon direct calculations from input link values	Expert review of values.
Council Management	Poor	Based upon assumptions	Expert review of assumptions
Domestic Pets	Average	Based upon uncalibrated iCAM domestic pets model	Expert review of assumptions and output data
Establishment Costs	Average	Based upon some local data	Expert review for more current data.
Estuary Water Quality	Poor	Based upon assumptions and iCAM combination model	Expert review of assumptions and hydrodynamic model of the lake
Estuary Flow	Average	Based upon assumptions and local modelling	Expert review of assumptions and output data
Fire Risk	Poor	Based upon assumptions	Expert review of assumptions
Fishing & Prawning (commercial)	Average	Based upon assumptions with some local information	Expert review of assumptions
Flood Risk	Good	Based upon interpretation of calibrated modelling	Expert review of results
Flora & Fauna	Average	Based upon iCAM combination model and some local data	Expert review of assumptions, and more up to date monitoring information
Government Costs	Average	Based upon indicative values in local report	Expert review of output data
Heritage	Poor	Based upon assumptions	Expert review of assumptions

Innes TN	Average	Based upon uncalibrated iCAM water quality model using some local data	Expert review of input and output data
Innes TP	Average	Based upon uncalibrated iCAM water quality model using some local data	Expert review of input and output data
Innes TSS	Average	Based upon uncalibrated iCAM water quality model using some local data	Expert review of input and output data
Innes Water Quality	Poor	Based upon assumptions and iCAM combination model	Expert review of assumptions and hydrodynamic model of the lake
Lake Productivity	Poor	Based upon assumptions and iCAM combination model	Expert review of assumptions
Local Revenue	Poor	Based upon assumptions with some local information	Expert review of assumptions
Migratory Birds	Poor	Based upon assumptions with some local information	Expert review of assumptions
Natural Aquifers	Currently not populated		Collect information and expert opinion on natural aquifers in the area
Recreation	Average	Based upon assumptions from literature and some local consultation	More thorough expert review
Reversion cost	Average	Based upon local report	Expert review for more current information
Salinity	Average	Based upon uncalibrated iCAM estuary model using some local data	Expert review of input and output data
Sea Grass	Average	Based upon some local data and the uncalibrated iCAM combination model	Expert review of assumptions
Tidal Flushing	Average	Based upon uncalibrated iCAM estuary model using some local data	Expert review of input and output data
Tourism	Poor	Based upon assumptions from broad local information	Expert review of assumptions
Water Level	Average	Based upon uncalibrated iCAM estuary model using some local data	Expert review of input and output data

Wetland Vegetation	Poor	Based upon some local data and the uncalibrated iCAM combination model	Expert review of assumptions

Excellent: Models based on local data, supported assumptions, expert review and calibrated/verified with measured (local) data. For direct changes in measured areas where derived from ground-truthed GIS interpretation. Simple yes/no output models.
Very good: Models based on local data, supported assumptions, expert review and calibrated/verified with measured (local) data which may be limited in extent
Good: Models supported by expert review or local data. May be calibrated/verified with measured (local) data which may be limited in extent or show some areas for improvement of model fit.
Average: Uncalibrated models or based on assumptions with some supporting local data or expert review.
Poor: Based on untested assumptions with little or no supporting local data or expert review.

Priority data collection areas identified by Robert Mezzatesta (Eco Logical Australia) are:

- nutrient concentration information in Lake Cathie, Cathie Ck and Lake Innes (P, N & TSS)
- policy information on runoff controls across the whole catchment (not just in Area 13/14)
- localised septics data (failure rate, leaching etc)
- updated flood modelling (current information is quite old)
- updated lake depths / bathymetry

4 SCENARIOS

In order to develop this Sustainability Assessment analysis a relatively small subgroup of scenario combinations were selected from the 64800 available in the Lake Cathie / Lake Innes CLAM. It was decided to focus on the following scenarios:

- Area 13 Thrumster development
- Area 14 Lake Cathie development
- Entrance management
- Lower estuary shoaling dredging
- Reversion of Lakes Innes to freshwater
- Sea level rise

These sets of scenarios are considered in isolation to each other. The impacts focused on are the likely consequence of the scenario options (i.e., the highest probability outcome) with particular reference to the following values:

- water quality,
- catchment flora and fauna, and
- economic variables.

The descriptions below for these scenarios are taken from the Lake Cathie / Lake Innes CLAM tool. Other scenarios available in the CLAM tool are described in Appendix 2.

4.1 Area 13 Thrumster development

A new "inland coastal town" is to be developed to accommodate a final population of over 11,300 residential in 5,100 dwellings varying from detached houses on large blocks to higher density townhouses and units located close to the town and neighbourhood centres.

Thrumster is planned to be employment self sufficient with 3,000 employees in the town centre, mixed use areas, a business park and capacity for proportion of workforce to work from home.

The project itself has a 20 year development period with targeted development staging and infrastructure provision.

Approximately 30% of the development will be located within the catchment of Lake Innes, which will include a population of about 3,340 in 1,500 dwellings. The proposed development will incorporate water sensitive urban design principles and controls throughout the proposed residential area to manage pollutants and runoff, such as the use of grassed swales, wetlands, sandfilters and vegetation buffers.

The current land use over the area of proposed development is:

Land Use	Area (ha)
Bushland/riparian/wetland	89
Unimproved pasture	134
Total	223

The major potential impacts from this development on Lake Innes include changes in water quality.

Scenario Options:
1. No change to current land uses
2. Full implementation of the project.
3. Partial implementation of the project (75%)

4.2 Area 14 Lake Cathie Development

The development of a new urban area, including an increase in the population of Lake Cathie village will accommodate about 2,500 people over about 75ha with the area roughly south of Lake Cathie and north of Ocean drive, draining into Lake Cathie.

Key components;
- Residential housing estate, small commercial shopping centre and other community facilities.
- Constructed wetland system for drainage attenuation.
- Cycleway and walkway system
- 40m vegetation buffer on all existing drainage lines

The current land use over the area of proposed development is:

Land Use	Area (ha)
Bushland/riparian/wetland	15
Unimproved pasture	40
Urban/Residential	17
Roads	2
Total	74

Scenario options
1. No change to current land uses.
2. Full implementation of the project.
3. Partial implementation of the project (75%)

4.3 Entrance Management

Ocean entrance of the system is regularly closed due to natural accretion of sand; Hastings council has a policy of opening the entrance when the water level reaches 1.6m Australian Height Datum.

There is some pressure on the seasonality of entrance opening – most efficient for the estuary is over the winter months, however, there is pressure to have he entrance open over the summer months to benefit tourism and recreational requirements.

The entrance opening regime impacts on waterbird breeding habitats, migration of fish and prawns in and out of the estuary, flood risk for existing development in Lake Cathie and estuary flushing regimes.

Scenario options

1. No change, continue with current policy
2. Modify policy to open entrance at 1.8m
3. Modify policy to open entrance at 1.4m
4. Full natural opening process
5. Open entrance at all times

4.4 Lower Estuary Shoaling/Dredging

To reduce the sand volume in the lower estuary and facilitate recreational activities such as swimming and boating without adversely impacting on water bird habitat east of Ocean Drive bridge.

Scenario options

1. No change to existing management.
2. Dredging

4.5 Reversion of Lake Innes to Freshwater

Lake Innes was once the largest freshwater lake on the NSW coast, prior to 1933 it was of State significance as a coastal freshwater habitat.

The loss of the freshwater habitat of Lake Innes is considered regionally critical. The reversion of the lake to fresh water will provide secure permanent breeding habitat for waterbirds and drought refuge for freshwater species. It will increase the available open freshwater on the mid north coast from 40ha to more than 700ha.

The closing of the lake will also result in increased aquatic vegetation biomass and a more complex lake margin, leading to increased species diversity, increase in frog and turtle species; and increase the available food supply/source for microbats and bird species.

Scenario options

1. No change
2. Reversion of the lake to a freshwater system by closing the lake off from Cathie Creek; removing any saline influence.
3. Natural Closure of lake entrance over time

4.6 Sea Level Rise

The sea level is predicted to rise in the future due to climate change. The climate change scenarios were estimated from Whetton and Holper (2001).

The options are to predict the increase in sea level in by the year 2050 and 2100. The predicted sea level rise (cm) from values in the year 2004 used here were:

Rate of sea level rise	2050	2100
Low	3.6	7.6
Medium	19.8	41.8
High	36	76

A triangular distribution was assumed to describe the probabilities of rates of sea level rise, with the minimum and maximum sea level rise for 2050 and 2100 defined from the low and high rates defined by Whetton and Holper (2001). The probability of the various rates in sea level rise are dependant on the amount of carbon dioxide released into the atmosphere, which in turn in reliant on the national and global policies. Research into likely policies in the future is beyond the scope of this study.

Scenario Options:
No change to current sea level
Predictions for year 2050
Predictions for year 2100

5 RESULTS FROM SCENARIO RUNS

5.1 Development of Area 13 Thrumster and Area 14 Lake Cathie

The full urban development for Areas 13 and 14 were run in isolation, and then in combination and the impact was considered for all nodes. Table 3 summarises the impacts of these scenarios on all nodes for which there was an impact. This impact is a qualitative assessment of the relative magnitude and direction of change in the variable compared to the 'do nothing' option. Thus a 'small increase' means that the variable is likely to have a value that is a bit bigger than it would have been under the 'do nothing' option.

Table 3. Impacts of the full development of Areas 13 and 14 on likely state values for impacted nodes.

Values	Full implementation of Area 13 Thrumster	Full implementation of Area 14 Lake Cathie	Full implementation of Area 13 and 14
Cathie TN	negligible	moderate increase	moderate increase
Cathie TP	negligible	large increase	large increase
Cathie TSS	negligible	very small increase	very small increase
Cathie WQ	negligible	moderate decrease	moderate decrease
Cost to Council	small increase	very small increase	small increase
Domestic Pets	moderate increase	negligible	moderate increase
Estuary Water Quality	very small decrease	very small decrease	small decrease
Fire Risk	moderate increase	small increase	moderate increase
Flora & Fauna	very small decrease	negligible	very small decrease
Innes TN	moderate increase	negligible	moderate increase
Innes TP	small increase	negligible	small increase
Innes TSS	small increase	negligible	small increase
Innes WQ	very small decrease	negligible	very small decrease
Proximity to Vegetation	large increase	large increase	large increase
Sea Grass	negligible	negligible	very small decrease

The following nodes were not impacted: Algal blooms, Council management, Establishment costs, Estuary flow, Fishing and prawning (commercial), Flood risk, Government costs, Heritage, Lake productivity, Local revenue, Migratory birds, Natural aquifers (not populated), Recreation, Salinity, Tidal flushing, Tourism, Water level, Wetland vegetation.

The table shows:

- urban development within the Cathie catchment (Area 14) leads to a moderate decrease in the Lake Cathie water quality mainly through increases in TN and TP loads. The close correlation between the catchment nutrient inputs and the impact upon the lake water quality is most likely due to the small size of Lake Cathie compared to its catchment, making it very responsive to the nutrient inputs. This is reflected in the values used in the iCAM combination model given in the Cathie TN and Innes TP inputs page in the CLAM.
- urban development within the Innes catchment (Area 13) leads to a very small decrease in the Lake Innes water quality despite a small to moderate increase in TN, TP and TSS loads. The small impact in the lake water quality from the catchment inputs is most likely due to the larger size of the lake compared to its catchment. Again this is reflected in the values used in the iCAM combination model given in the Innes TN and Cathie TP inputs pages in the CLAM.
- either development (Area 13 or 14) is predicted to generate a very small decrease in the total estuary water quality, but both developments together leads to a small decrease. The decrease in the estuary water quality is likely to be the explanation for the very small decrease in seagrass if both developments were to occur.
- if any of the proposed urban developments were to occur then the increase in the proximity of the urban area to vegetation is likely to be large. Consequently fire risk is also likely to increase but is more significant for the Area 13 development then for Area 14. This change in fire risk would be the cause for the very small decrease predicted for flora and fauna following the Area 13 development.
- domestic pets are likely to moderately increase if the Area 13 development was to be approved. This increase along with the increases in fire risk, are likely to lead to a very small to small increase in the council costs.

Figures 4 and 5 show the impact of urban development on the total nitrogen loads to Lake Cathie and Lake Innes, respectively. The predicted TN loads for Lake Innes are much larger than for Lake Cathie with the smallest class for Lake Innes being <3000kg/yr, while the maximum class for Lake Cathie is only >2000kg/yr. Again the likely explanation for this is that the Lake Innes catchment is much larger than Lake Cathie catchment, and is therefore more likely to contribute a higher nutrient load under the same type of land use. However, because Lake Cathie is a much smaller water body it is more sensitive to the nutrient loads, shown by almost a 20% increase in the likelihood of a large decrease in water quality (Figure 6) compared to in Lake Innes (Figure 7).

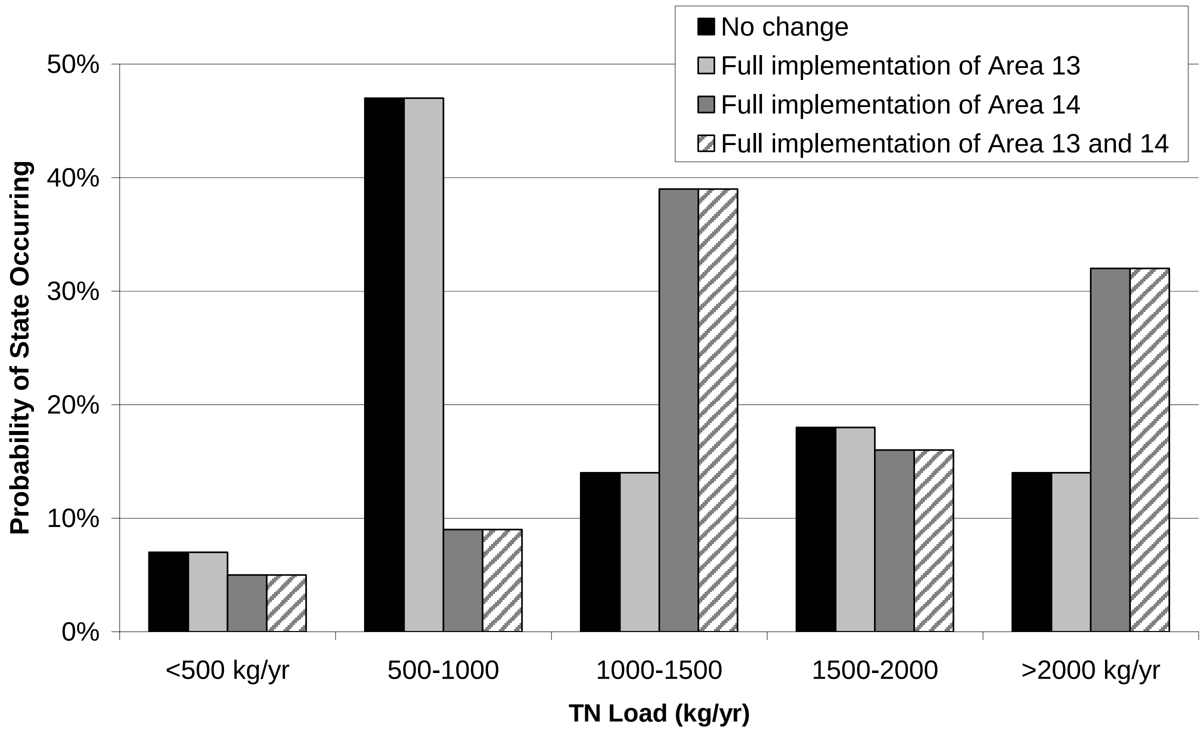

Figure 4. Probability of change in Lake Cathie total nitrogen (TN) under the urban development scenarios

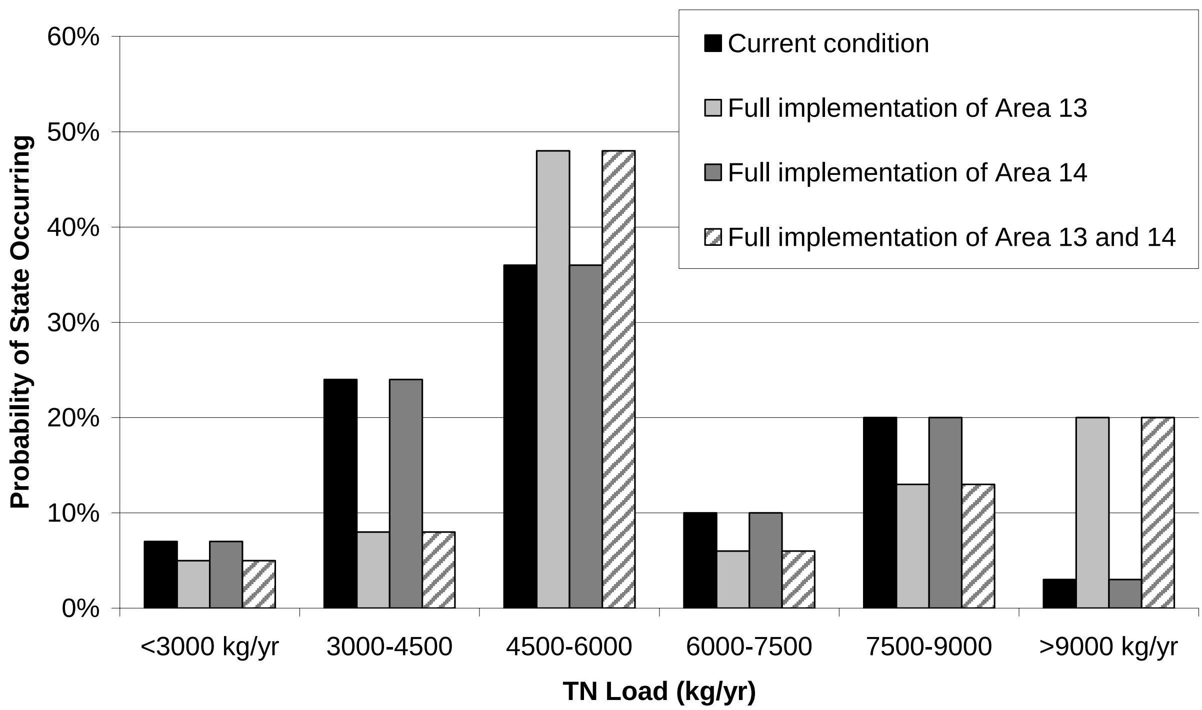

Figure 5. Probability of change in Lake Innes total nitrogen (TN) under the urban development scenarios

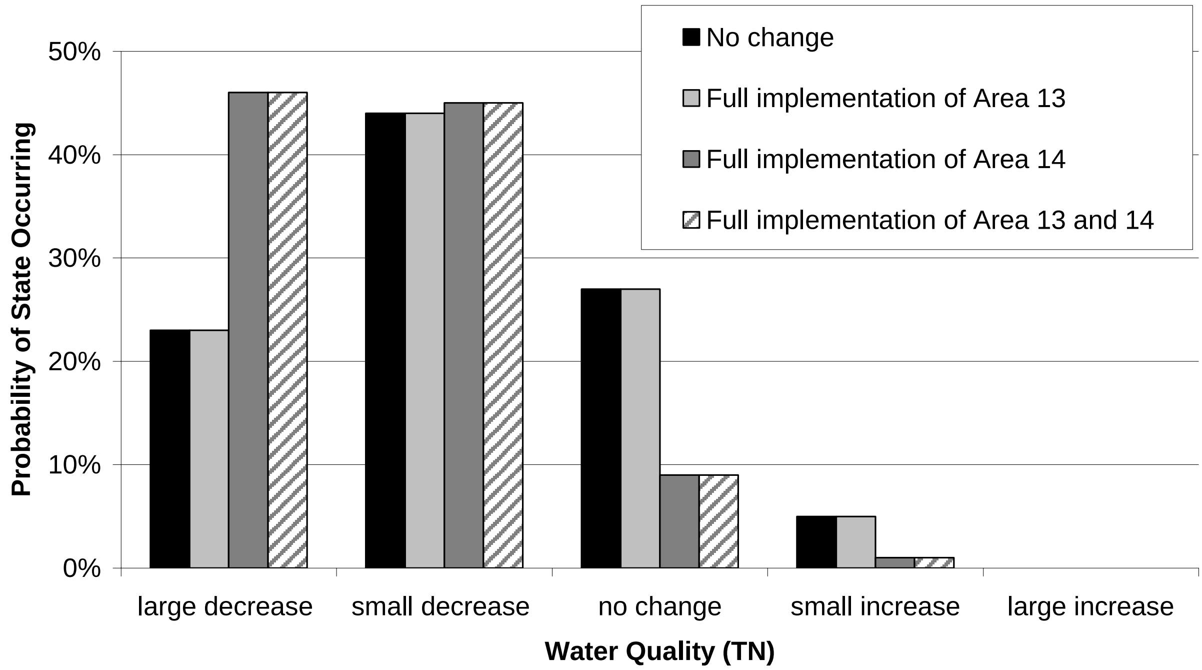

Figure 6. Probability of change in Lake Cathie water quality (TN) under the urban development scenarios

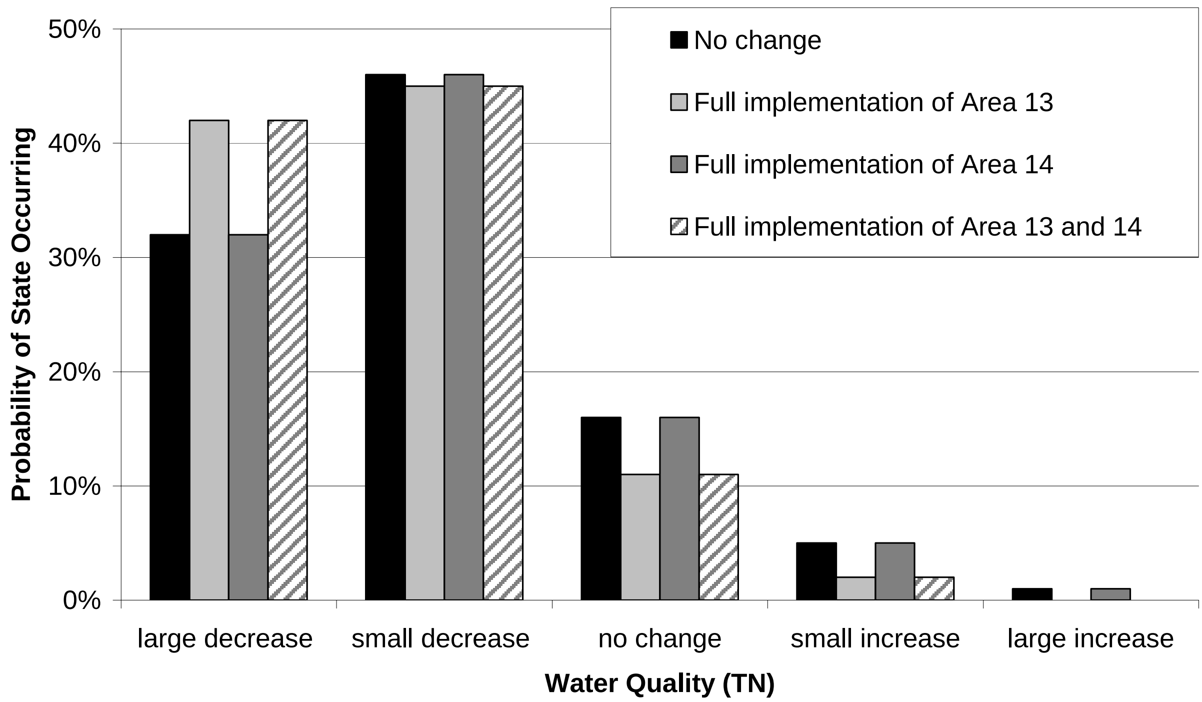

Figure 7. Probability of change in Lake Innes water quality (TN) under the urban development scenarios

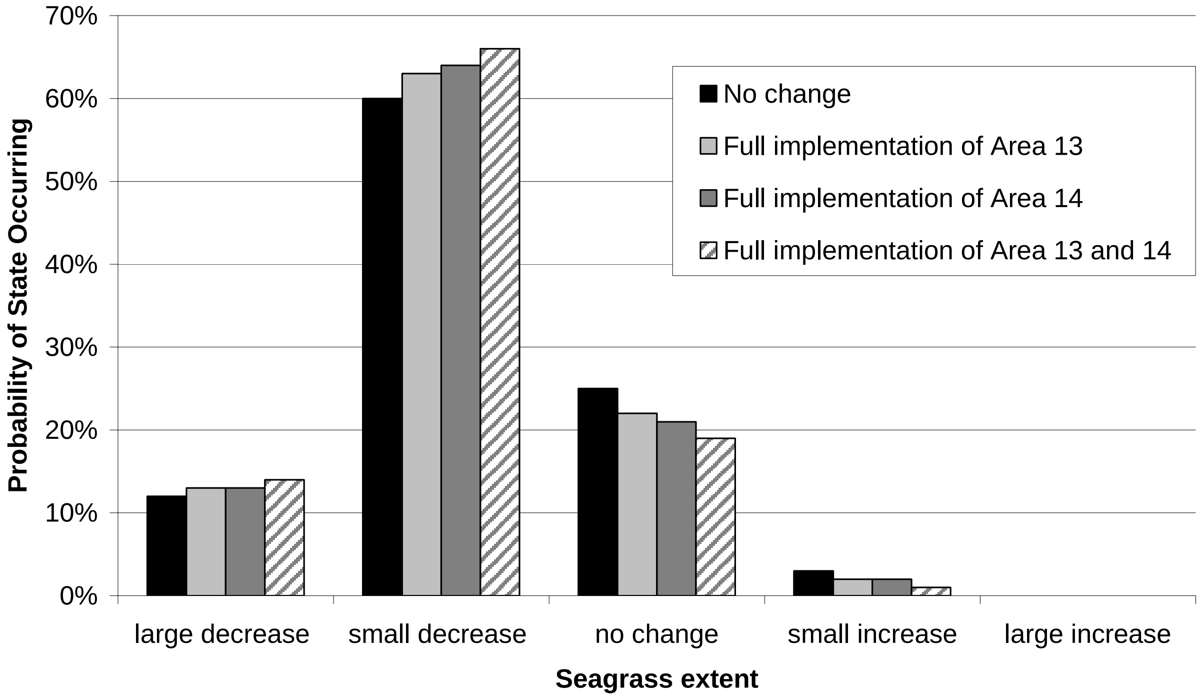

Figure 8. Probability of change in seagrass under the urban development scenarios

The follow-on impact from the change in water quality on estuary flora, such as seagrass, is predicted to be minimal (Figure 8). However greater spatial resolution of the nutrient and sediment loads coming into the lakes should be considered because localised concentration of nutrients and sediment around tributary outlets can have a significant impact upon local, and perhaps isolated, patches of seagrass. Therefore the actual impact upon the lake seagrass population could be greater, and these results should be treated with caution. Seagrass represents an important ecological community for overall habitat health and fish/prawns breeding areas and so any actions that are predicted to increase the risk to a seagrass population should be further investigated before any actions are taken.

5.2 Combination Impacts Between Reversion of Lake Innes to Freshwater, Lower Estuary Shoaling and Dredging, Entrance Management and Sea Level Rise

A suite of independent and combination options between the reversion of Lake Innes to freshwater, lower estuary shoaling and dredging, entrance management and sea level rise were selected and run for a comparison of the integral impacts upon the Lake Cathie / Lake Innes water system. The options selected for each scenario were:

- Reversion of Lake Innes to freshwater: No change, and Natural closure of lake over time
- Lower estuary shoaling and dredging: No change, and Dredge
- Entrance management: No change, and Full natural opening process, and
- Sea Level Rise: No change, and Level predicted for the year 2100.

Tables 4 and 5 summarise the impacts of these scenarios on all nodes for which there was an impact, Table 4 being with the current sea level and Table 5 being with the sea level rise predicted for the year 2100. This impact is a qualitative assessment of the relative magnitude and direction of change in the variable compared to the ‘do nothing’ option. Thus a ‘small increase’ means that the variable is likely to have a value that is a bit bigger than it would have been under the ‘do nothing’ option.

Unaffected nodes were the same regardless of the sea level, being: Proximity to vegetation, Cathie TP, Cathie TN, Cathie TSS, Cathie Water Quality, Cost to council, Domestic pets, Establishment costs, Estuary flow, Fire risk, Innes TN, Innes TP, Innes TSS, Innes Water Quality, Natural aquifers (no data).

There were not many impacts from sea level rise (2100) that were evident above the impacts from the other scenarios. The summary below describes the impacts presented in Tables 4 and 5, and unless otherwise stated sea level rise did not change the impact:

- Natural entrance management overrides the other scenario impacts and creates a large increase in tidal flushing and a large decrease in salinity. This is most likely to be because under a natural regime the lake will be closed for longer periods of time thus decreasing in salinity, but only large freshwater inflows will break the entrance berm leading to a more complete flushing out to the ocean. The large increase in tidal flushing also creates a large increase in the estuary water quality, which is the most likely reason for the moderate decrease in the likelihood of algal blooms. Note that salinity is assumed to represent an average value across both lakes except in the case where Lake Innes is reverted back to freshwater, where salinity only reflects the salinity in the Lake Cathie and Creek system closest to the ocean entrance.
- Dredging the lower estuary leads to a small increase in council management, but reverting to a natural entrance management regime creates a small decrease in council management. Together a very small increase in council management is predicted.
- Natural reversion to freshwater in Lake Innes or a change to natural entrance management creates a moderate decrease in commercial fishing and prawning, and with both scenarios together the decrease is large. However these scenarios were also predicted to lead to a moderate and large increase in flora and fauna and lake productivity, respectively. Migratory birds also have a very small, to small positive reaction to the natural reversion to freshwater in Lake Innes and a natural entrance management regime.
- Natural reversion to freshwater in Lake Innes or change to a natural entrance management without a change in the sea level leads to a very small to small increase in flood risk. An increase in the sea level alone leads to a moderate increase in the flood risk, and if the entrance management was changed to a natural regime the impact would be even larger.
- Matt Rogers of the Port Macquarie-Hastings Council has questioned the insensitivity of recreation and tourism, expecting a more significant impact associated with moving to a natural entrance opening conditions as an individual scenario. This may be related to the quality of data used in the model and warrants further investigation.

Table 4. Impacts of the independent and combination between the reversion of Lake Innes to freshwater, lower estuary shoaling and dredging, and entrance management, with the current sea level on likely state values for impacted nodes.

Values	Reversion to freshwater	Dredge lower estuary	Reversion to freshwater & dredge lower estuary	Entrance management	Entrance management & reversion to freshwater	Entrance management & dredge lower estuary	Entrance management, dredge lower estuary & reversion to freshwater
Algal blooms	negligible	negligible	negligible	moderate decrease	moderate decrease	moderate decrease	moderate decrease
Council Management	negligible	small increase	small increase	small decrease	small decrease	very small increase	very small increase
Estuary Water Quality	negligible	negligible	negligible	large increase	large increase	large increase	large increase
Fishing & Prawning (commercial)	moderate decrease	negligible	moderate decrease	moderate decrease	large decrease	moderate decrease	large decrease
Flood Risk	very small increase	negligible	very small increase	small increase	small increase	small increase	small increase
Flora & Fauna	moderate increase	negligible	moderate increase	large increase	large increase	large increase	large increase
Government Costs	large increase	negligible	large increase	negligible	large increase	negligible	large increase
Heritage	moderate increase	negligible	moderate increase	negligible	moderate increase	negligible	moderate increase
Lake Productivity	moderate increase	negligible	moderate increase	large increase	large increase	large increase	large increase
Local Revenue	very small increase	negligible	very small increase	very small increase	very small increase	very small increase	small increase
Migratory Birds	very small increase	negligible	very small increase	small increase	small increase	small increase	small increase
Recreation	negligible	very small increase	very small increase	very small decrease	very small decrease	negligible	negligible
Salinity	negligible	negligible	negligible	large decrease	large decrease	large decrease	large decrease
Sea Grass	small increase	negligible	small increase	moderate increase	moderate increase	moderate increase	moderate increase
Tidal Flushing	negligible	negligible	negligible	large increase	large increase	large increase	large increase
Tourism	negligible	very small increase	very small increase	very small decrease	very small decrease	negligible	negligible
Water Level	negligible	negligible	negligible	large increase	large increase	large increase	large increase
Wetland veg	moderate increase	negligible	moderate increase	large increase	large increase	large increase	large increase

Table 5. Impacts of the independent and combination between the reversion of Lake Innes to freshwater, lower estuary shoaling and dredging, and entrance management, with the sea level predictions for 2100 on likely state values for impacted nodes.

Values	Sea Level Rise (2100)	Reversion to freshwater, SLR (2100)	Dredge lower estuary, SLR (2100)	Reversion to freshwater & dredge lower estuary, SLR (2100)	Entrance management, SLR (2100)	Entrance management & reversion to freshwater, SLR (2100)	Entrance management & dredge lower estuary, SLR (2100)	Entrance management, dredge lower estuary & reversion to freshwater, SLR (2100)
Algal blooms	negligible	negligible	negligible	negligible	moderate decrease	moderate decrease	moderate decrease	moderate decrease
Council Management	negligible	negligible	small increase	small increase	small decrease	small decrease	very small increase	very small increase
Estuary Water Quality	negligible	negligible	negligible	negligible	large increase	large increase	large increase	large increase
Fishing & Prawning (commercial)	negligible	moderate decrease	negligible	moderate decrease	moderate decrease	large decrease	moderate decrease	large decrease
Flood Risk	moderate increase	moderate increase	moderate increase	moderate increase	moderate increase	large increase	moderate increase	large increase
Flora & Fauna	negligible	moderate increase	negligible	moderate increase	large increase	large increase	large increase	large increase
Government Costs	negligible	large increase	negligible	large increase	negligible	large increase	negligible	large increase
Heritage	negligible	moderate increase	negligible	moderate increase	negligible	moderate increase	negligible	moderate increase
Lake Productivity	negligible	moderate increase	negligible	moderate increase	large increase	large increase	large increase	large increase
Local Revenue	negligible	very small increase	negligible	very small increase	very small increase	very small increase	very small increase	small increase
Migratory Birds	negligible	very small increase	negligible	very small increase	small increase	small increase	small increase	small increase
Recreation	negligible	negligible	very small increase	very small increase	very small decrease	very small decrease	negligible	negligible
Salinity	negligible	negligible	negligible	negligible	large decrease	large decrease	large decrease	large decrease
Sea Grass	negligible	small increase	negligible	small increase	small increase	moderate increase	small increase	moderate increase
Tidal Flushing	negligible	negligible	negligible	negligible	large increase	large increase	large increase	large increase
Tourism	negligible	negligible	very small increase	very small increase	very small decrease	very small decrease	negligible	negligible
Water Level	small increase	small increase	small increase	small increase	large increase	large increase	large increase	large increase
Wetland veg	very small increase	moderate increase	very small increase	moderate increase	large increase	large increase	large increase	large increase

- Recreation is quite insensitive to these scenarios but does reflect a very small increase from dredging in the lower estuary and a very small decrease from natural entrance management, which is probably due to the expected small changes in boat navigation access. These changes are also reflected in tourism.
- Natural reversion to freshwater in Lake Innes creates a large increase in government costs because a thorough investigation needs to be funded before any plan to revert the lake can be carried out. This cost would only be marginally offset by a very small increase in local revenue following the conversion. Together with a change to natural entrance management the local revenue is likely to undergo a small increase, but this still appears very unlikely to offset the costs of the required investigation to revert Lake Innes to a freshwater system.
- With the current sea level, natural reversion to a freshwater system in Lake Innes generates a small increase in seagrass, while changing to a natural entrance management regime overrides this impact and creates a moderate increase in seagrass. With an increase in the sea level, natural entrance management is predicted to lead to only a small increase in seagrass, which is likely due to the lake water level becoming too deep to support a thriving seagrass population. The impacts of the deeper water level are slightly offset by the reversion back to a freshwater system because the latter creates a moderate increase in the heritage value, which in combination with sea level rise and natural entrance management leads to a moderate increase in seagrass.
- Under the current sea level wetland vegetation is likely to increase moderately following the reversion back to freshwater, and undergo a large increase under natural entrance management. With sea level rise the wetland vegetation is likely to undergo a very small increase, but this impact is overridden by the other human management activities discussed above.
- The values predicted to be impacted upon by sea level rise are flood risk, seagrass and wetland vegetation, which are all primarily connected through water level.

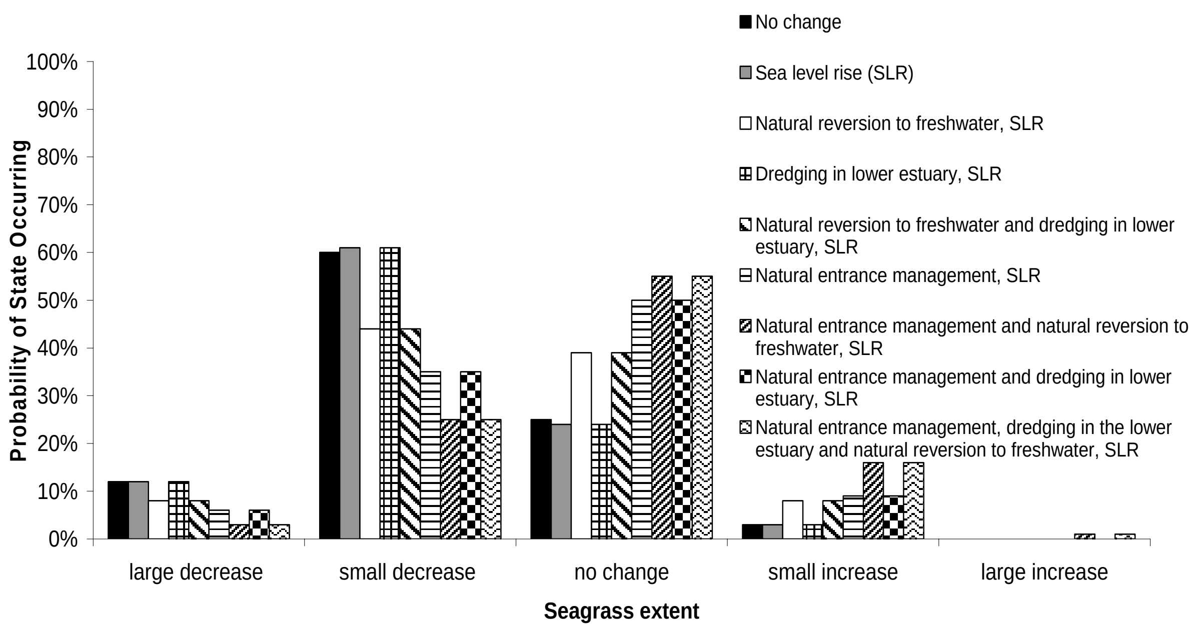

Figure 9. Probability of change in seagrass under the sea level rise, reversion to freshwater, dredging in the lower estuary and entrance management scenarios

Figure 9 shows that current belief is that the area of seagrass in the Lake Cathie / Lakes Innes systems is currently under decline and if nothing is done to improve the lake environment for sea grass then the decline will continue. Currently, the majority of seagrasses exist in

Cathie Creek, with only a small amount in Lake Innes and none in Lake Cathie. Reverting to more natural forms of management such as a natural reversion to freshwater in Lake Innes and changing to a natural entrance management regime are the most likely of the tested actions to stabilise and increase seagrass in the Lake Cathie / Lake Innes systems. Sea level rise and dredging in the lower estuary have a negligible impact on the current declining trends.

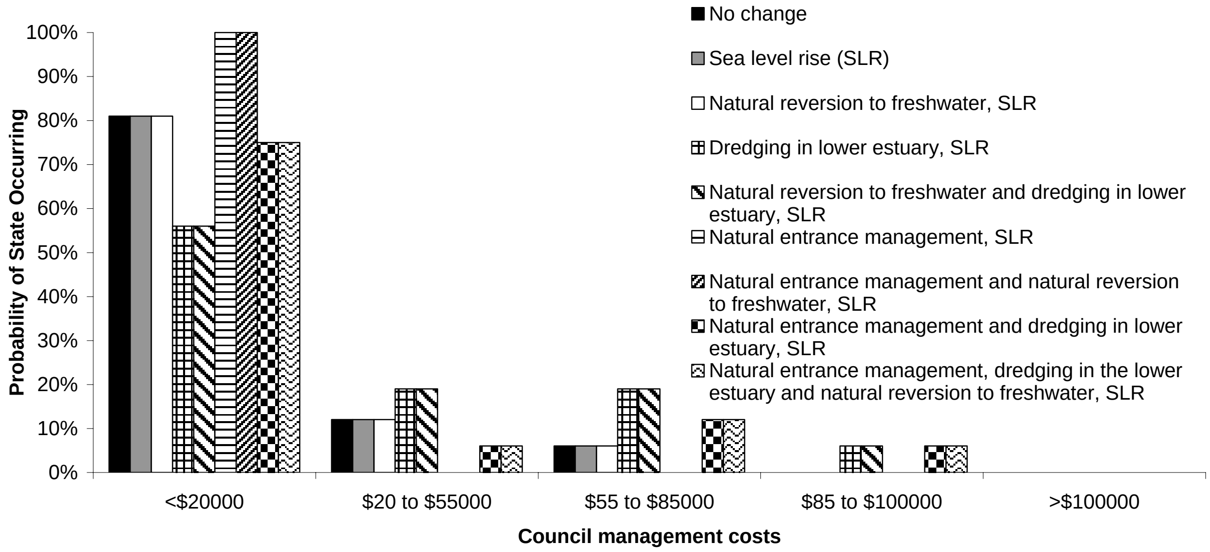

Figure 10. Probability of change in council management under the sea level rise, reversion to freshwater, dredging in the lower estuary and entrance management scenarios

Figure 10 shows that sea level rise or a natural reversion to freshwater in Lake Innes, on their own, are not expected to change the council management costs from the current costs. Dredging in the lower estuary is more likely to cost the council more, increasing the likelihood of a cost from $55 to $85000 from 6 to 19%. The dredging scenario on its own, or in combination with a natural reversion to freshwater in Lake Innes, is likely to be the most expensive option for the council. If council were to change to a natural entrance management regime then their management costs would possibly decrease, therefore employing natural entrance management could offset some, but not all of the costs for the dredging of the lower estuary. However, natural entrance management would also increase flood risk in the catchment, which represents a cost to council. Note that these costs have not been incorporated into this CLAM but are worthy of further investigation.

However, as Tables 4 and 5 show, dredging has an almost negligible positive impact upon recreation and tourism. Figure 11 shows that there is most likely to be no change in tourism from all the scenarios tested here. Natural entrance management is more likely to decrease tourism than the current management, and dredging the lower estuary may slightly offset that impact changing the probability of a decrease in tourism from 24% for natural entrance management alone to 21% if dredging also occurred. However dredging and natural entrance management when carried out together have a 17% chance of increasing tourism, which is 1% greater than if dredging was carried out without the change to natural entrance management. This illustrates that there is a reasonable degree of uncertainty in the likely impact from these management options on tourism, which can be explained by the poor quality of data used to populate this component of the model (Table 3). One would have to question the appropriateness of dredging the lower estuary, increasing the cost for council management for possibly no return to the catchment tourism, until better information was available.

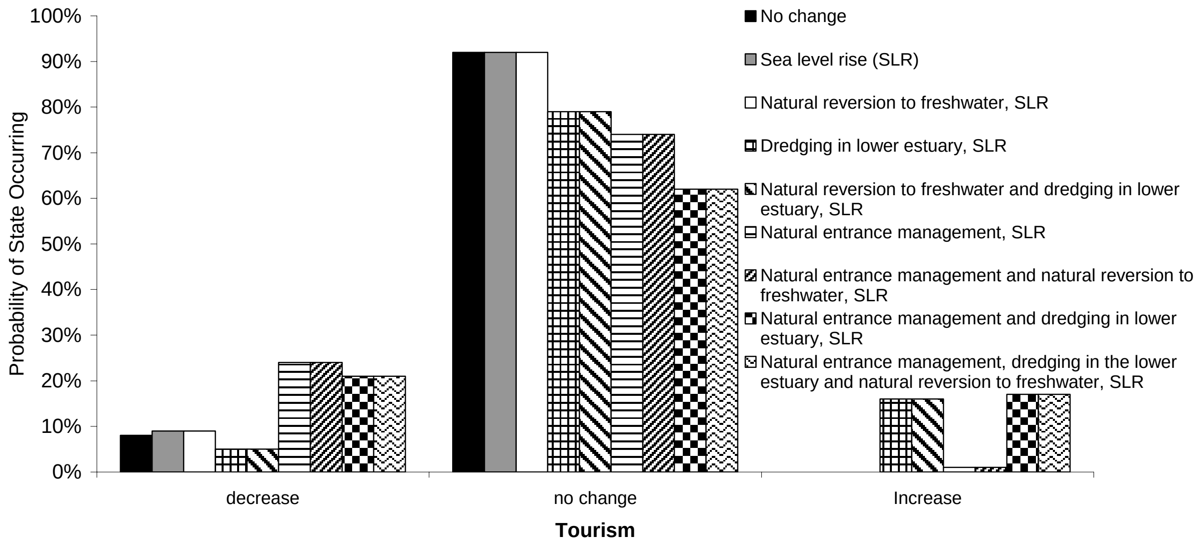

Figure 11. Probability of change in tourism under the sea level rise, reversion to freshwater, dredging in the lower estuary and entrance management scenarios.

6 DISCUSSION OF THE RESULTS

This Sustainability Assessment report has provided a sample of results for the management of urban development and the Lake Cathie/ Lake Innes water way through reversion to freshwater, dredging, and entrance management as well as of the impacts of sea level rise. These options are a small subset of the total number of scenarios which can be considered by the Lake Cathie / Lake Innes CLAM and as such do not provide conclusive evidence of the 'best' management options available.

These results show:

- Both options for urban development (Area 13 Thrumster and Area 14 Lake Cathie) had negative impacts upon the estuary water quality and follow-on impacts on seagrass. The predicted changes were quite small but given the expanse of the Lake Cathie/ Lake Innes systems a more spatial study on the links between the catchment water quality inputs and seagrass populations within the lakes would be beneficial to confirm the magnitude of the impacts.
- The impact upon the catchment and its waterway is almost always overridden by the other human activities explored in this report.
- Dredging and shoaling in the lower estuary increases council management costs for only a small increase in recreation and tourism.
- Changing back to more natural management of the lakes, such as naturally reverting Lake Innes to freshwater and employing a natural entrance management regime, is the most likely way to slow and perhaps reverse the decline in seagrass within the lake system.

The results shown here as well as the table of data quality provided in section 3.3 demonstrate some of the features of the data that has been used to underpin the Lake Cathie / Lake Innes CLAM. The Natural aquifers variable does not contain data because there was not any available. In addition variables on the hydrodynamics and aquatic ecosystems and economic value had poor data quality. These were algal blooms, Cathie water quality, cost to council, council management, estuary water quality, fire risk, heritage, Innes water quality, lake productivity, local revenue, migratory birds, tourism and wetland vegetation. The CLAM is able to accept updates of such information over time as it becomes available. This should be considered in conjunction with other identified data collection requirements (see section 3.3).

7 ACKNOWLEDGEMENTS

This project has been funded by the Northern Rivers Catchment Management Authority. The authors would particularly like to acknowledge the efforts of Roger Stanley of the Northern Rivers CMA who has managed the project and provided considerable time and knowledge to this work. In addition the time and efforts of the project Reference Group need to be acknowledged. This group consisted of John Schmidt of Department of Environment and Climate Change, Brian Hughes of Coastcare (initially), David Greenhalgh of the Solitary Islands Marine Park Authority, Marcus Riches of the Department of Primary Industries, Steve Channels of the Department of Lands (initially) and Steve Jensen of the Department for Planning. Finally this CLAM and subsequent results would not have been possible without the efforts of Port Macquarie - Hastings Shire Council, in particular Matt Rogers. We would also like to acknowledge the community and industry input to this CLAM. Those involved included but were not limited to Glenn Atkinson (Department of Environment and Climate Change), Jack Jones (Lake Cathie Progress Association), Sandy McClimont (Residents Action Group).

8 REFERENCES

Borget R, Dove M, Gustafson P & Lake B (1997) A field investigation pertaining to the management of Lake Cathie, NSW. Report prepared for Hastings Council and NPWS. GEOG 4010 Field Project. School of Geography UNSW. November

Brydon, N., Letcher, R.A., Merritt, W.S. and Ticehurst, J.L. (2007). Coastal Lake Assessment and Management (CLAM) Tool : User Guide. iCAM Technical Report (Version 2). iCAM Technical Report 2007/03, Integrated Catchment Assessment and Management Centre, Australian National University, Canberra.

Department of Environment and Water Resources (DEWR) (2007) EPBC Act Protected Matters Search Tool. Search Conducted 30 March 2007. [online]. Available: http://www.environment.gov.au/erin/ert/epbc/index.html

GHD (2004) Maintenance Dredging of Lake Cathie. Report produced for Hastings Shire Council

Hastings Council (2001) Entrance opening Strategy.

Healthy Rivers Commission (2002). "Independent Inquiry into Coastal Lakes", April 2002, http://www.begavalley.nsw.gov.au/Environment/estuaries/pdfs/Healthy_Rivers.pdf

Hudson W (2001) Water Quality and Nutrients within the Lake Innes Catchment. A thesis submitted to the Dept of Geography & Environmental Science, University of Newcastle, as partial fulfilment of the requirements for the degree of Bachelor of Environmental Science, with Honours. May.

Intergovernmental Panel on Climate Change [IPCC], 2001. Special Report on Emission Scenarios. Nakicenovic, N., Swart, R. (Editors.) Intergovernmental Panel on Climate Change.

Merritt, M., Brydon, N. Letcher R. and Ticehurst, J. (2007), Ensuring the sustainability of Coastal Lakes in NSW Northern Rivers: Coastal Lakes Assessment and Management (CLAM) Tool User Workshop (Phase 2), iCAM Technical Report 2007/02, Integrated Catchment Assessment and Management Centre, Australian National University, Canberra

NSW Department of Natural Resources (2006) Lake Innes and Lake Cathie. Estuaries in NSW. [online] available at: http://www.dlwc.nsw.gov.au/estuaries/inventory/innes.shtml

NSW DNR Multi Attribute Mapping - Land Use Mapping. GIS data received March 2007.

NSW NPWS (1999) Lake Innes NR Plan of Management. November.

Richards D (2006) AREA 13 Thrumster LES. Prepared for Port Macquarie Hastings Council. May

Richards D (2006) Area 13 Urban Investigation Area Structure Plan Urban Design Guidelines. Prepared for Hastings Council. April

Susan Cooper and Ass & Ecograph (1999) Vegetation Management Plan (Draft for Consultation). October.

Port Macquarie Hastings Council (2003 & 2004) Lake Cathie and Bonnie Hills Urban Design Masterplan and Environmental Study for Stage 1A Urban Land Release
Port Macquarie Hasting Council (2005) Lake Cathie Opening Strategy. Brochure.
Rissik, D., Nelson, P., White, J., Hatfield, E., and Cenedese, S., (2003), Preparation of Sustainability Assessments for Coastal Lakes, Draft project proposal, 2nd December 2003.
Ticehurst, J.L., Merritt, W., and Rissik, D. (2006), Coastal Lakes Assessment and Management Tool: Application and tailoring workshop, iCAM Technical Report 2006/01, Integrated Catchment Assessment and Management Centre, Australian National University, Canberra
Ticehurst, J.L. Newham, L.H. T., Rissik, D., Letcher, R.A. and Jakeman A.J. (2007), A Bayesian network approach for assessing the sustainability of coastal lakes, *Environmental Modelling and Software*, 22(8):1129-1139.
UMWELT (2004) A tale of two lakes. Managing Lake Cathie and Lake Innes for Improved Ecological and Community outcomes. Issues and Options. Report prepared for DEC, PWD. February.
Webb, McEown & Associates (1994) Lake Cathie/Lake Innes Estuary Management Plan. Produced for Hastings Council. May
Whetton, P. and Holper, P. (2001), More droughts, more flooding rains, CSIRO Media release Reference: 2001/111, May 07 2001. downloaded 12/11/2004, http://www.csiro.au/index.asp?type=mediaRelesase&id=ClimateHotter.

APPENDIX 1. SUMMARY OF NODES IN THE LAKE CATHIE LAKE / LAKE INNES CLAM TOOL

Node	Description	Output States	Units
Algal blooms	Changes in the possibility of algal blooms within the estuary	Decrease, No change, Increase	
Cathie TN	Inputs of total nitrogen to Lake Cathie.	<500, 500-1000, 1000-1500, 1500-2000, >2000	(kg/yr)
Cathie TP	Inputs of total phosphorus to Lake Cathie.	<100, 100-150, 150-200, 200-250, 250-300, >300	(kg/yr)
Cathie TSS	Inputs of total suspended solids to Lake Cathie.	<5000, 5000-8000, 8000-12000, >12000	(kg/yr)
Cathie Water Quality	Change in overall water quality in Lake Cathie as a result of management scenarios	large decrease, small decrease, no change, small increase, large increase	
Cost to Council	Potential increase in Council costs as a result of the implementation of management actions	no change, increase	
Council Development Cost	Initial costs for the modification of bridges	0, 250000, 500000	($)
Council Management Cost	management costs to Council for entrance management and dredging	*Utility variable*	($ / year)
Council Management	Estimated annual management costs to Council to undertake management scenarios	<20,000; 20-55,000; 55-85,000; 85-100,000; >100,000	($)
Domestic Pets	Representation of changes in the number of domestic pets in the catchment from urban development	<50 increase; 50-75 increase; 75-100 increase; >100 increase	(%)
Establishment Costs	Establishment costs due to the modification of bridges	0; 250,000; 500,000	($)
Estuary Water Quality	Increase or decrease in overall estuary water quality as a result of management within Lake Innes and Lake Cathie	large decrease, small decrease, no change, small increase, large increase	
Estuary Flow	Estimation of change in estuarine water flows into Lake Cathie due to the modification of bridges	No Change, Increase	
Fire Risk	Changes in the potential for fire risk in the catchment	Decrease, No change, Increase	
Fishing & Prawning (commercial)	The estimated degree of decrease to the commercial fishing and prawning catch in the estuary	>50% decrease, <50% decrease, No change	(%)

Flood Risk	Estimates potential changes to the flooding levels in metres	1 - 1.4, 1.4 - 1.6, 1.6 - 1.8, 1.8 - 2, >2	(m)
Flora & Fauna	Changes in habitat for flora and fauna within the catchment	large decrease, small decrease, no change, small increase, large increase	
Government Costs	Establishment costs of the investigation and assessment of the reversion of Lake Innes to freshwater	0, 850000, 30000	($)
Heritage	Change in natural heritage values such as terrestrial and aquatic vegetation as a result of reverting Lake Innes to freshwater	No change, Increase	
Innes TN	Inputs of total nitrogen (kg/year) to Lake Innes.	<3000, 3000-4500, 4500-6000, 6000-7500, 7500-9000, >9000	(kg/yr)
Innes TP	Inputs of total phosphorus (kg/year) to Lake Innes.	<400, 400-500, 500-600, 600-700, 700-800, >800	(kg/yr)
Innes TSS	Inputs of total suspended solids (kg/year) to Lake Innes.	<40000, 40000-60000, 60000-80000, >80000	(kg/yr)
Innes Water Quality	Increase or decrease in overall water quality in Lake Innes as a result of management scenarios	large decrease, small decrease, no change, small increase, large increase	
Lake Productivity	Changes in lake productivity within the estuary	large decrease, small decrease, no change, small increase, large increase	
Local Revenue	Changes in the potential local revenue in the area	decrease, no change, increase	
Migratory Birds	Changes in the suitable habitat for migratory birds in the estuary	Decrease, No change, Increase	
Natural Aquifers	Changes to the level of exploitation of the natural aquifer due to management changes in the catchment	(Note: This node is not currently populated with data)	
Proximity to Vegetation	Percentage increase or decrease in the proximity of native vegetation to urban areas as a result of urban development	No Change, 0-25, 25-50, 50-75, >75 increase	(%)
Recreation	Change in recreational amenity, including recreational fishing in the estuary from management options that may effect changes in estuary water flows	Decrease, No Change, Increase	
Reversion cost	Initial costs for the reversion of lake Innes to freshwater ($)	0, 30,000, 850,000	($)

Salinity	Lake salinity, represented as a range in concentration	<22; 22 to 24; 24 to 26; 26 to 28; 28 to 30; 30 to 32; >32	(practical salinity units - PCU).
Sea Grass	Changes in the extent of sea grass in the estuary	large decrease, small decrease, no change, small increase, large increase	
Tidal Flushing	Percentage change in the lake flushing with the ocean.	>-10;-10 to -5; -5 to -1; -1 to 1; 1 to 5; 5 to 10; >10	(% change)
Tourism	Changes in the tourism levels in the catchment	Decrease, No change, Increase	
Water Level	Lake depth	<0.75; 0.75 to 1.75; 1.75 to 2.5; >2.5	(m)
Wetland Vegetation	Changes in wetland vegetation within the estuary	large decrease, small decrease, no change, small increase, large increase	

APPENDIX 2. ADDITIONAL SCENARIO GROUPS AVAILABLE IN THE LAKE CATHIE / LAKE INNES CLAM TOOL

- Modification of Bridges
- Regulate Domestic use of Groundwater
- Dredge Spoil Management
- Mid-Estuary Shoaling and Dredging

Modification of Bridges
The construction of Kenwood Drive bridge and Ocean Drive bridge has resulted in a change to natural flows once existing in the mid and lower estuary of Lake Cathie and Cathie Creek. Modification of the structures may contribute to a change in the estuarine flows.

Regulate Domestic use of Groundwater
A valuable long term groundwater resource exists under the coastal sands. It is currently being exploited for domestic bores. Contamination will increase with development. Usage of groundwater resources may increase with an increase in population

Dredge Spoil Management
Spoil that is dredged from lower or mid estuary may be used in and around the estuary for stabilisation and reclamation works in order to deal with erosion currently occurring within the estuary.

Mid Estuary Shoaling and Dredging
To reduce the sand volume in the mid estuary and facilitate recreational activities such as swimming and boating without adversely impacting on water bird habitat. Reduce the formation of stabilised, grassed sand banks west of the Ocean Drive Bridge.